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H-3-18

MEMORANDUM TO: A. O. Neiser, State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report (Interim):
"Grooving Pavement Centerlines
for Lane Demarcation;" KYP-18

Rainy nighttime driving is imperiled by poor visibility, glare, and slipperiness. Slipperiness, however, is also a daytime peril in wet weather. The problem of glare and poor visibility seems to be an abiding one. Certainly, bold ingenuity is admissible. Delineators mounted on posts at the shoulder edge seem rather impractical in some ways, but they satisfy a need which so far has not been met by other means. For instance, centerlines and edge lines become obscured by snow. Lane-delineating lines, unfortunately, are least effective when they are needed the most -- i.e. on a rainy night.

Two basic approaches to rectifying this problem have emerged quite recently: one is to increase the proudness and (or) size of the reflex-reflective elements so that they protrude above the water on the pavement; the other is to provide better drainage of water away from the optical surfaces. The latter approach is exemplified by grooving the pavement as described in the report being submitted herewith. Distinctive improvement of visibility was achieved. However, the cost of the grooving could weigh heavily upon the Department's striping budget. Based on this limited experiment, grooving would cost about fifteen times more than merely painting the stripe.

Grooving has not been evaluated on asphaltic concrete surfaces.

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Some discussion of possible alternatives may be helpful here. All other innovations evidently involve raised elements of some kind. For instance, aggregate chips may be cemented to the pavement with asphalt or glue and then painted over and reflectorized with glass beads. The aggregate chips, if well isolated, provide inclined surfaces and drainage in the "valleys". This concept is illustrated in Fig. 3 (hereof). A few years ago, the 3M Company developed a ceramic chip (Scotch Rock) which was coated with reflective beads; these were glued to the pavement or other surfaces with epoxy resin. They were very bright until they became dirty; surfaces which were not scrubbed by traffic remained dirty; and the reflectivity "died". Fig. 1 illustrates the normal, beaded paint stripe -- which is readily inundated by a thin film of water. There practically all of the light is reflected ahead inasmuch as the beads are obscured and inasmuch as the water presents a mirror-like surface to the light (angle of incident light exceeds the critical grazing angle and is not refracted downward into the water). Fig. 2 illustrates a thick or raised line which is very much like the normal paint stripe -- except that drainage is more favorable. Drainage would be further enhanced if the beads were more isolated -- that is, the beads would tend to "pimple" above the water if they were isolated beyond meniscus limits. Fig. 4 shows larger beads more sparsely dispersed; there the effects of water are further minimized; but the likelihood of dislodging the beads from their sockets by snow-plows and traffic has increased. cursory estimates of water depths on pavements indicate that the apex of the bead should stand at least one-eighth inch above the pavement. Fig. 5 illustrates an additional refinement in the use of large beads. This concept perfects the "cat eye" and may be extended to sizes in the order of one inch or larger. They could be spaced several feet apart along the line. Basically the large bead captures the light, focuses it onto a secondary reflex reflector, and returns the light toward the source. Prototype models of this system have been improvised in our laboratory, and they have proven to be highly efficient. It is apparent in Fig. 5 that the capturing lense need not be truly spherical.

Perhaps we have been remiss heretofore by not advancing these notions more vigorously. Nevertheless, grooving is a reality which is immediately achievable.

The cutting machines developed by Christensen are capable of forming "rumble strips" and of removing scaled concrete such as on bridge decks. Of course, others have experimented with more-or-less continuous grooving of pavements in an effort to alleviate hydroplaning. I have entertained ideas of grooving pavements only to the extent of controlling treacherous cross-flows of water -- such as at super-elevated and warped sections and at points where the grade-slope exceeds the crown in the pavement. Diagonal or transverse grooves at intervals might relieve a hydroplaning condition.

Respectfully submitted,



Jas. H. Havens
Director of Research

A. O. Neiser, State Highway Engineer
Chairman, Research Committee

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JHH/slw

Attachments

cc's: Research Committee

Assistant State Highway Engineer, Research and Development
Assistant State Highway Engineer, Planning and Programming
Assistant State Highway Engineer, Pre-Construction
Assistant State Highway Engineer, Construction
Assistant State Highway Engineer, Operations
Assistant State Highway Engineer, Staff Services
Assistant Pre-Construction Engineer
Assistant Operations Engineer
Executive Director, Office of Computer Services
Executive Director, Office of Equipment and Properties
Director, Division of Bridges
Director, Division of Construction
Director, Division of Design
Director, Division of Maintenance
Director, Division of Materials
Director, Division of Photogrammetry
Director, Division of Planning
Director, Division of Research
Director, Division of Right of Way
Director, Division of Roadside Development
Director, Division of Rural Roads
Director, Division of Traffic
Division Engineer, Bureau of Public Roads
Chairman, Department of Civil Engineering, University of Kentucky
Associate Dean for Continuing Education, College of Engineering
All District Engineers

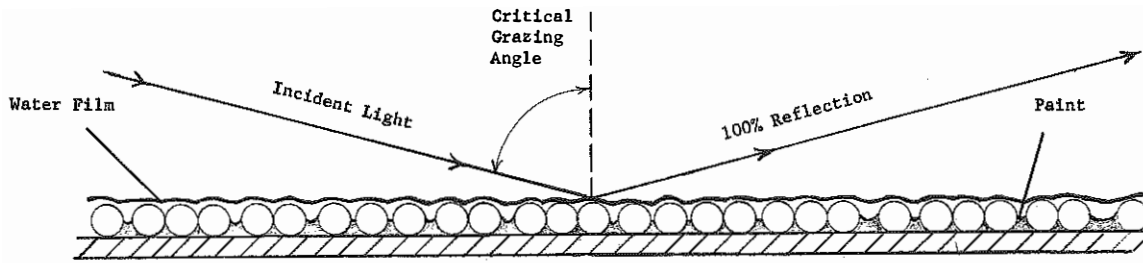


Figure 1 -- Beaded Paint

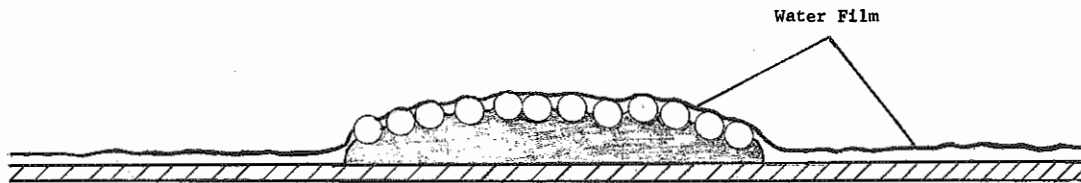


Figure 2 -- Cross Section of Raised Stripe

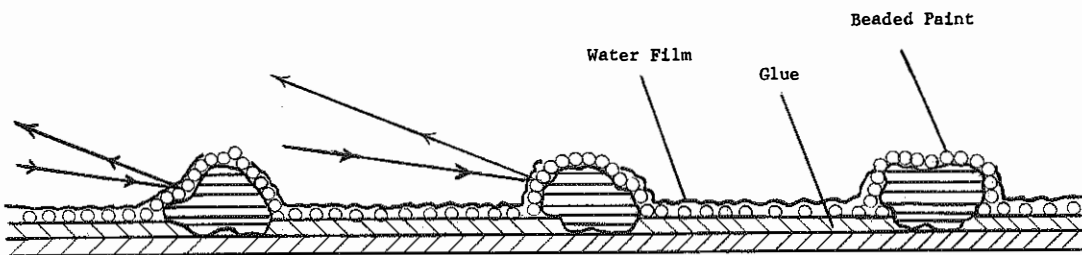


Figure 3 -- Beaded Aggregate Chips

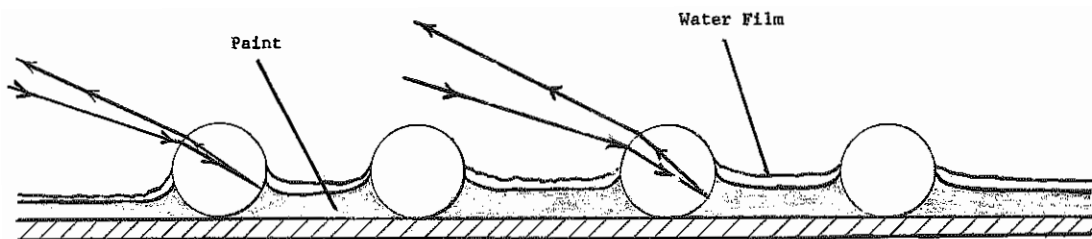


Figure 4 -- Large -- Diameter Beads

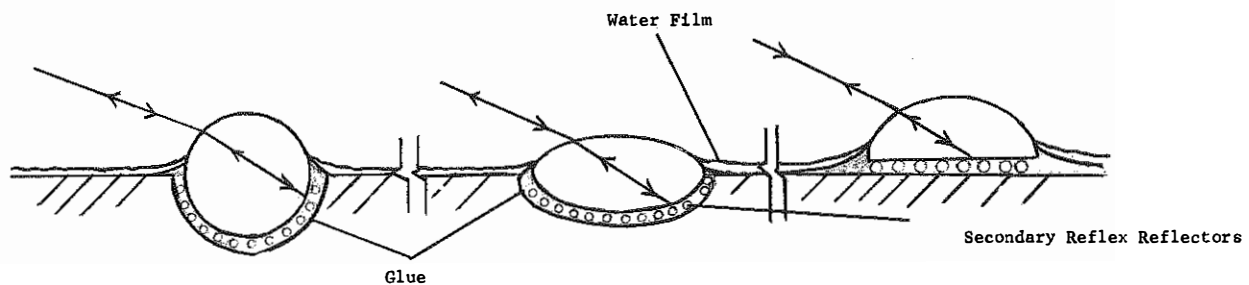


Figure 5 -- Coatings of Small Beads

Research Report

Interim Placement and Performance Report

**GROOVING PAVEMENT CENTERLINES
FOR LANE DEMARCATION**

KYP-18

by

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Chief Research Engineer

and

G. R. Garner
Research Engineer

Division of Research
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

October 1969

INTRODUCTION

Lane demarcation is conventionally accomplished by use of white traffic paint placed as a skip line. Most traffic paints are beaded by premixing glass beads in the paint, by drop-on applications, or a combination of the two. The retroreflective properties of the beads greatly enhance nighttime visibility during dry weather; however, visibility of the lines is practically nil during wet nighttime driving. Submerged beads cannot redirect the light when the need for guidance is most critical. Thermoplastic striping materials have been used to varying degrees of success by numerous agencies. Wet nighttime visibility of thermoplastics, as experienced in Kentucky, is generally far superior to that of conventional beaded paints. Thermoplastics are placed at a thickness of 125 mils and are thereby less likely to become submerged than conventional paints, which are placed at film thicknesses in the order of 14 mils and dry to approximately 8 mils.

Late in 1965, the California Division of Highways reportedly issued a policy requiring the use of raised pavement markers as a replacement for most painted lines on future freeways and conventional highways. Other agencies have employed raised markers in various forms and have reported excellent to good wet nighttime visibility for markers remaining in place. Major disadvantages of the thermoplastics and raised markers are:

1. they are quite expensive as compared to paint,
2. they break or crack under traffic, and
3. the present loss is high as a result of traffic and snow removal equipment.

In addition, the raised markers are rather difficult to install.

Christensen Diamond Services, Inc. of Salt Lake City, Utah, reportedly introduced the concept of grooving centerlines in an attempt to provide a rumble effect for alerting drivers straying outside their traffic lanes. It was later observed that the painted grooves were more visible at night during wet weather than were normal paint stripes. The concept of grooving and painting centerlines was thus promoted, and, as a result, several test sections were placed on Nebraska highways in the summer of 1968. In order to evaluate the effectiveness of grooving the centerline prior to striping, a section of newly constructed pavement of I 71 in Carroll County, Kentucky, was chosen for an experimental installation. This interim report covers installation of the grooves and a preliminary evaluation of their value to date.

SITE AND INSTALLATION DETAILS

A section of portland cement concrete pavement on Project I 71- 2 (15) 37 was chosen for the trial installation for several reasons. The pavement had been recently constructed, was not open to traffic, and had not been centerlined. Additionally, the section contained several 3-degree curves and valleys and crests with grades to 4 percent. The section was designed and constructed in accordance with conventional interstate standards and has two sets of dual lanes divided by a 60-foot (minimum) depressed median. Grooves were placed in both the northbound and southbound lanes between stations 1845+00 and 1985+00, as noted on the site map in Figure 1. Conventional centerlines on Kentucky highways are placed at 40-foot intervals with a 15-foot stripe and 25-foot skip. For more realistic visual comparative purposes, grooves were placed 15 feet in length at 80-foot intervals, resulting in a sequence of 15-foot grooved and painted line, 25-foot skip, 15-foot ungrooved but painted line, and then a 25-foot skip.

Christensen Diamond Services, Inc. performed the grooving under a contractual agreement with the Department of Highways at a unit price of \$0.325 per foot of grooved line. The grooving was performed in accordance with *Special Provision No. 00 -- Grooving Portland Cement Concrete Pavements for Traffic Stripes* which is appended hereto for convenient reference. Paint striping was performed under normal procedures by Departmental forces. The groove configuration used on the project is shown on the first page of the Special Provision. The crests of the corrugations were cut 1/8 to 1/16 inch below the pavement surface in an attempt to minimize wear of the paint. One to three transverse drainage grooves were placed for each 15-foot longitudinal centerline groove in order that the grooves might better serve their intended function.

The equipment, designated as the Concrete Planer, used in grooving is shown in Figure 2. The machine is powered by a Ford V8-185HP industrial engine, weighs approximately 7 tons and has an overall width and length of 4 feet by 12 feet, respectively. An operator's console provides complete control of all machine functions and an automatic blender controls the depth of cut for the power-driven, 36-inch cylinder. The machine is fully automatic in that the depth of cut may be initially set and then will remain constant for various pavement irregularities normally encountered. Various textures, configurations, and widths of cuts up to 36 inches are possible through arrangement and spacing of diamond-studded cutting heads. The longitudinal configuration head and one of the transverse groove heads are shown right and left, respectively, in Figure 3. The cylinder is shown being loaded with the longitudinal grooving head in Figure 4. Figure 5 shows the housing which is placed over the cutting cylinder for enclosing the water spray during grooving operations.

The cutting heads are 4 inches wide and approximately 6-3/4 inches in diameter and are composed of Huxton carbide and industrial grade diamonds. The longitudinal grooving head contains approximately 2400 diamonds and the transverse grooving heads contain about 3500 diamonds, sized in the order of 35 diamonds per karat. The cutting cylinder rotates at 1250 rpm and produces a remarkably smooth cut. The machine was operated at a rate of approximately 7 feet per minute during longitudinal grooving operations and could be moved from the end of one groove to the beginning of a new groove in about 35 seconds. Longitudinal grooves were placed throughout the entire project and then the heads were changed and transverse grooves were placed in a second pass. Cutting time per transverse groove was 5 seconds and these were cut slightly lower than the troughs of the longitudinal grooves to insure complete drainage. The length, location, and number (1 to 3) of transverse grooves per longitudinal groove naturally were governed by the pavement grade and cross slope.

Grooving operations were commenced on June 25 and were completed on July 1, 1969, in 5 working days. In all, 174 and 176 longitudinal grooves were placed in the southbound and northbound lanes, respectively. Grooves were omitted at stations 1868+21 and 1877+85 in the southbound lanes since these were locations of armored-edged expansion dams of two closely spaced bridges. The numbers of transverse grooves were 303 and 253, for averages of 1.74 and 1.44 per longitudinal groove, for the southbound and northbound lanes, respectively. Upon completion of the grooving operations, the grooves were broomed and flushed with water to remove dust. The sequence of grooving operations is listed in the following table.

| DATE | GROOVE | STATIONS | LANES | NUMBER CUT |
|---------|--------------|-------------|-------|------------|
| June 25 | longitudinal | 1985 - 1913 | SB | 91 |
| June 26 | longitudinal | 1913 - 1845 | SB | 83 |
| June 26 | longitudinal | 1845 - 1865 | NB | 27 |
| June 27 | longitudinal | 1865 - 1943 | NB | 95 |
| June 30 | longitudinal | 1943 - 1985 | NB | 54 |
| June 30 | transverse | 1985 - 1845 | NB | 253 |
| July 1 | transverse | 1845 - 1985 | SB | 303 |

The striping machine was the type which could be operated manually or automatically for slip lining. Even though the machine was set for automatic operation and readjusted frequently, the operator experienced difficulty in beginning and ending paint application on the grooves. On the average, approximately a 2-foot length of each 15-foot grooved section did not receive paint. The operator was extremely proficient in lining transversely over the grooves and only three grooves remained unpainted. Approximately 64 percent (225) individual grooves were fully painted transversely and the remaining 36 percent were 5/6 to 1/2 covered. The paint was applied at a wet film thickness of 14 mils and contained 4 pounds of premixed glass beads per gallon. Drop-on beads were applied at a rate of 2 pounds per gallon. Figure 6 is a close-up view of a grooved and painted section. Transverse cracks to the right of the transverse groove in Figure 6 were not a result of the grooving -- the pavement is continuously reinforced and contains similar transverse cracks at approximately 6-foot intervals throughout.

OBSERVATIONS

The roadway has been in service since July 15, 1969, and it is thus too early to evaluate paint wear on the grooved stripes. Debris collecting in the groove troughs and obscuring the paint has not been a problem to date, and it is thought that the grooves will be self cleaning. During dry, daylight conditions, little or no variation in light reflectance was observed between the grooved and ungrooved lines. Shadows on the bottom of the grooves caused a very slight decrease in visibility of the grooved stripes, which varies with declination of the sun and relative roadway orientation. Under wet, daylight conditions, the grooved lines were more visible than ungrooved lines, although glare from the wet pavement surface reduced this effect somewhat. The grooved and ungrooved lines are equally visible on dry nights. On wet nights, the ungrooved lines are to a large degree invisible and the grooved lines are much more readily visible. Under the light to average rainfall conditions so far observed, the grooved lines have drained very efficiently and have been much more visible than ungrooved lines. The grooved lines are in all cases superior in wet weather, although the effect is more pronounced on curves and steeper grades. Figures 7 through 12 depict the stripes under various wet weather conditions.

KENTUCKY DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 00
GROOVING PORTLAND CEMENT CONCRETE
PAVEMENT FOR TRAFFIC STRIPES

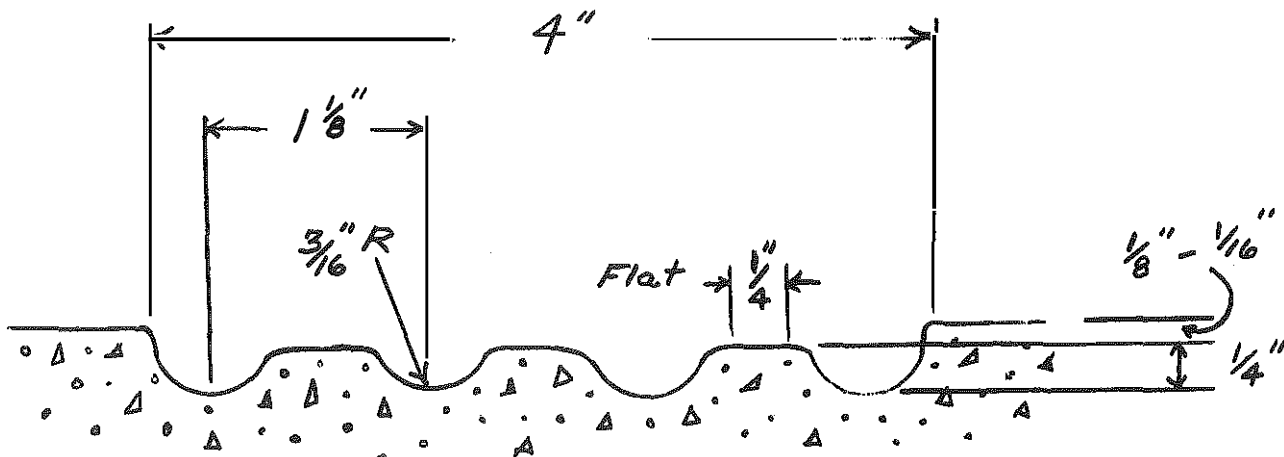
This special Provision, or designated portion (s) hereof, shall apply only when so indicated on the plans, in the proposal, or in the bidding invitation and shall supersede any conflicting provisions of the Department's Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This Special Provision covers the construction procedures for grooving the surface of portland cement concrete pavements prior to painting for pavement markings. This work shall consist of grooving the surface at the designated locations and satisfactory removal of all dust and other substances resulting from the grooving operation. This Special Provision does not include placement of the paint stripe.

II. CONFIGURATION

The groove shall be cut in such a manner that it will be corrugated similar to the section included herein. The top of the corrugations shall be flat for a width equal to approximately one-fourth the corrugation width. The radius of each trough shall be $\frac{3}{16}$ inch. The centers of the interior troughs shall be $1\frac{1}{8}$ inches from the outside edge of their adjacent exterior trough. The depth of the troughs shall be $\frac{1}{4}$ inch.



GROOVING CONFIGURATION

III. CONSTRUCTION METHODS

The pavement shall be grooved at the locations and for the distances noted on the plans, proposal, or invitation. The top of the lands shall be cut to an elevation of $1/16$ to $1/8$ inch below that of the normal pavement surface. The centerline of the groove shall not be more than 2 inches in the transverse direction from the location indicated on the plans, proposal, or invitation. Necessary measures shall be taken to prevent the machine from slipping to the low side on superelevated sections. The machine shall be constructed and operated in such a manner that the surfaces of the grooves will be of uniform texture and be free of chipped or broken sections. Sections which do not meet the approval of the Engineer shall be patched with an epoxy- sand mortar. Patched areas one or more feet in length shall be grooved after sufficiently cured.

One to three transverse grooves shall be cut per 15-foot section in order to provide adequate drainage. The number and length of transverse grooves will be dependent upon the grade and cross slope of the pavement. These grooves shall be not less than $2\frac{1}{2}$ inches in width and shall be of such depth to adequately drain all troughs of the corrugated section. These grooves shall be cut in the transverse direction to the point such that the outlet elevation of the bottom of the groove is equal to or lower than the elevation of the lowest point of the longitudinal section.

All dust and other debris resulting from the grooving operation shall be completely removed from the grooved and pavement surfaces. Water and/or air used in the cleaning operation shall be free of oil, grease, or other contaminants that may be detrimental to adherence of paint to the surface.

IV. BASIS OF PAYMENT

Payment will be made at the contract price per lineal foot of accepted longitudinal groove, which price shall be full compensation for all grooving, cleaning, patching, and incidentals necessary to complete the work.

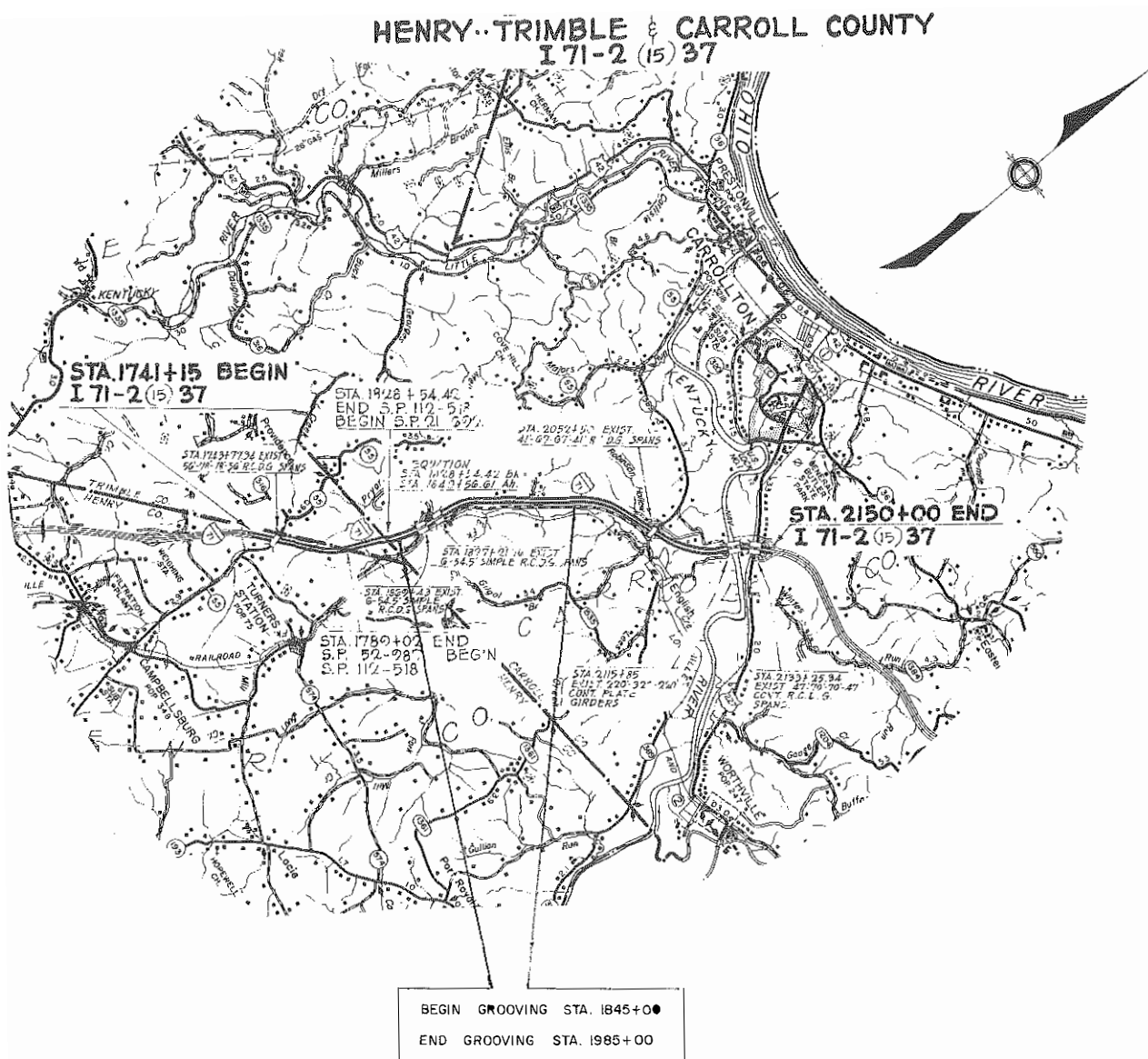


FIGURE 1 - Project Location Map

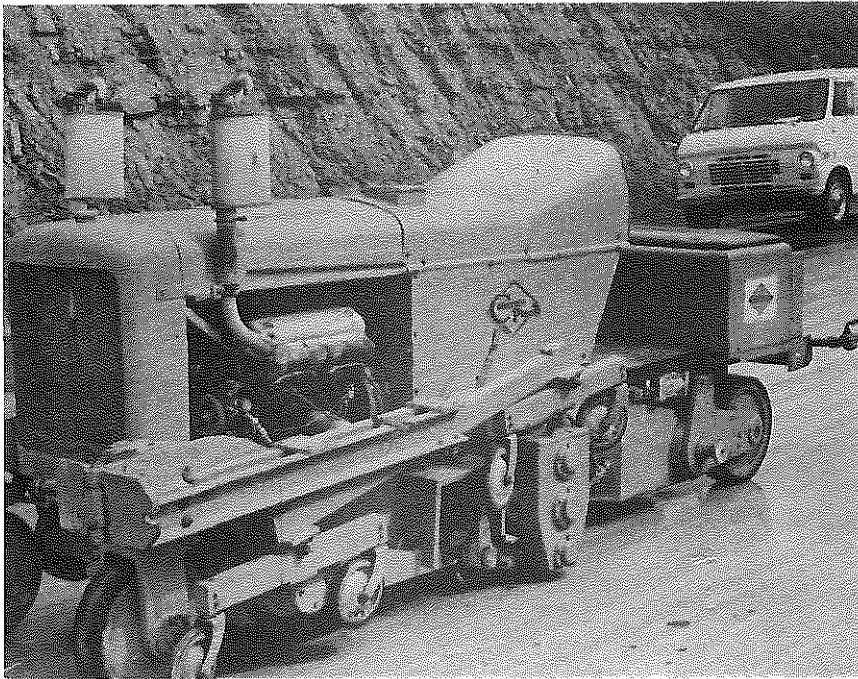


FIGURE 2 - Grooving Machine

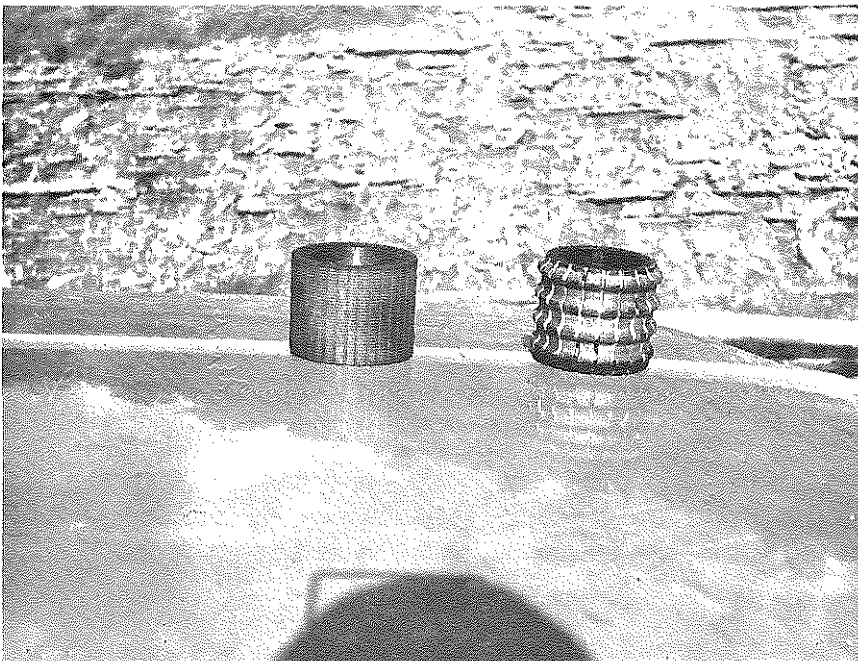


FIGURE 3 - Cutting Heads

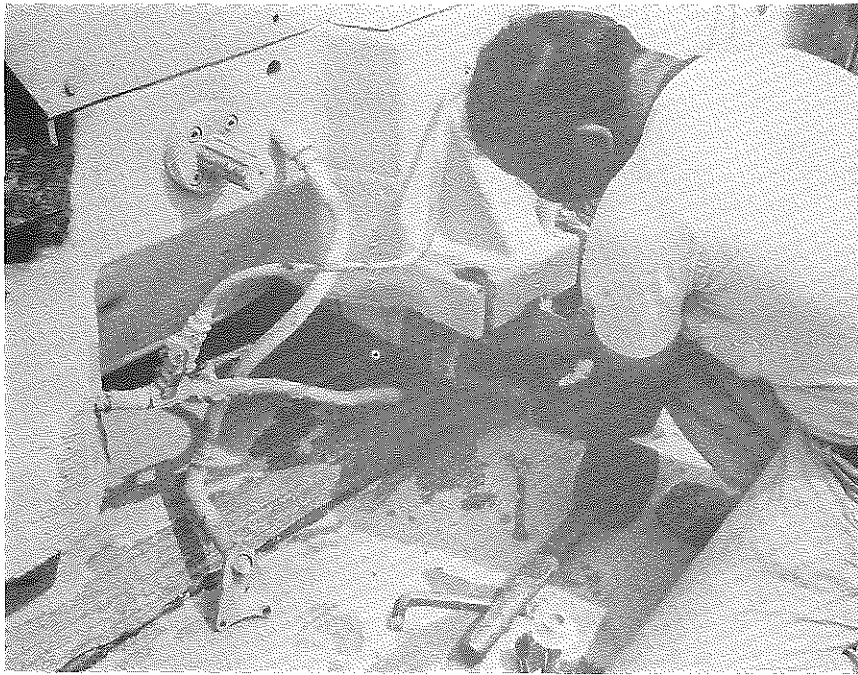


FIGURE 4 - Loading Cylinder with Longitudinal Grooving Head

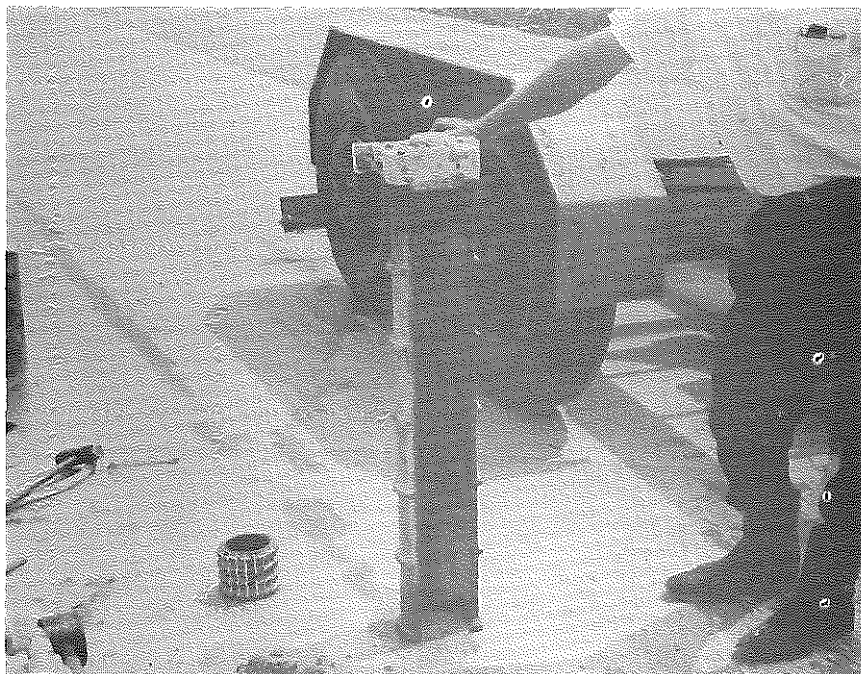


FIGURE 5 - Housing for Water Spray

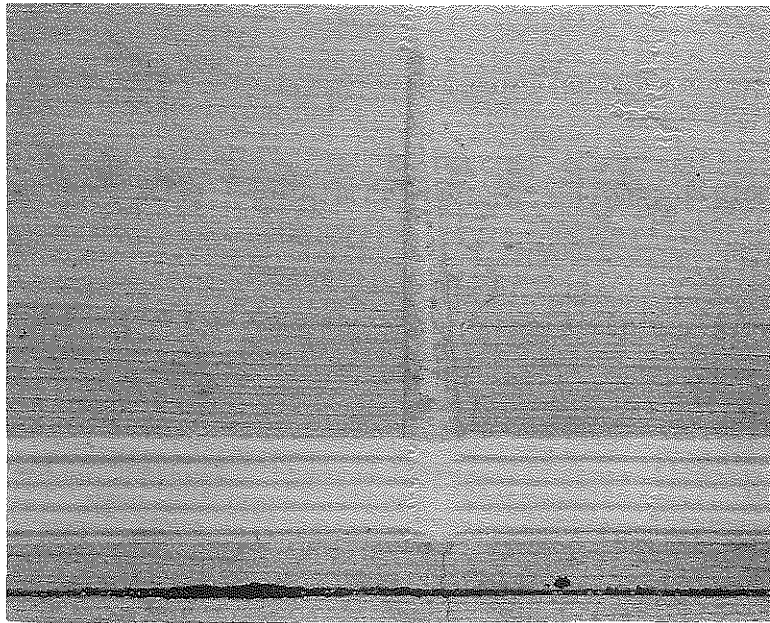


FIGURE 6 - Grooved and Painted Stripe

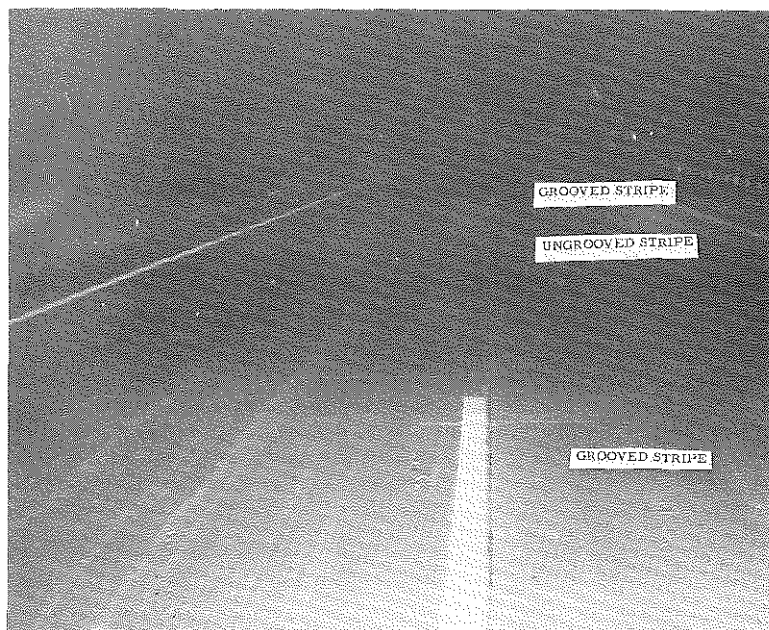


FIGURE 7 - Grooved Stripe Performance During Wet, Nighttime Conditions

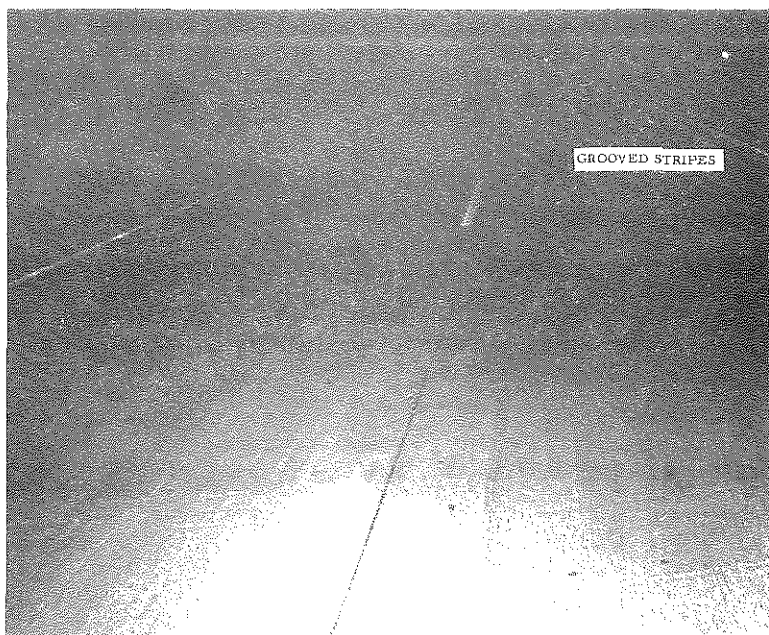


FIGURE 8 - Grooved Stripe Performance During Wet, Nighttime Conditions

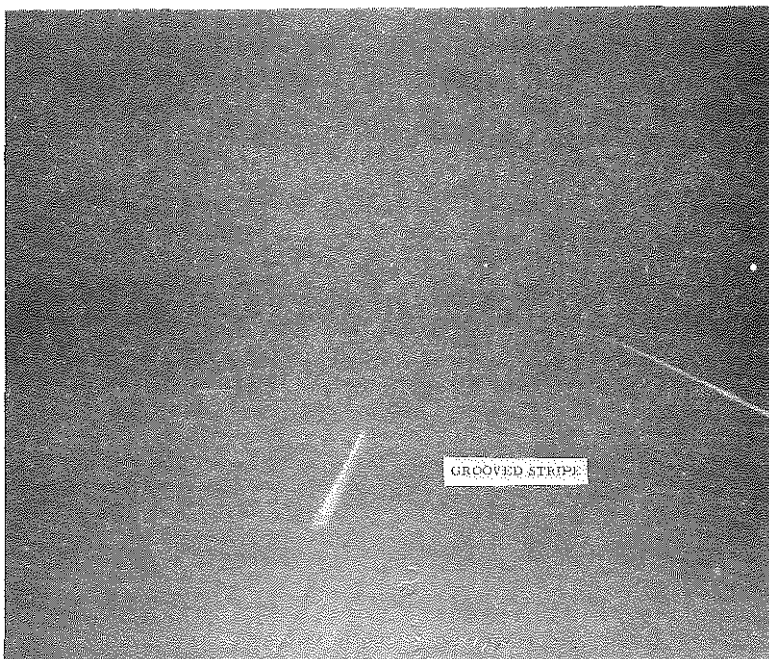


FIGURE 9 - Grooved Stripe Performance During Wet, Nighttime Conditions

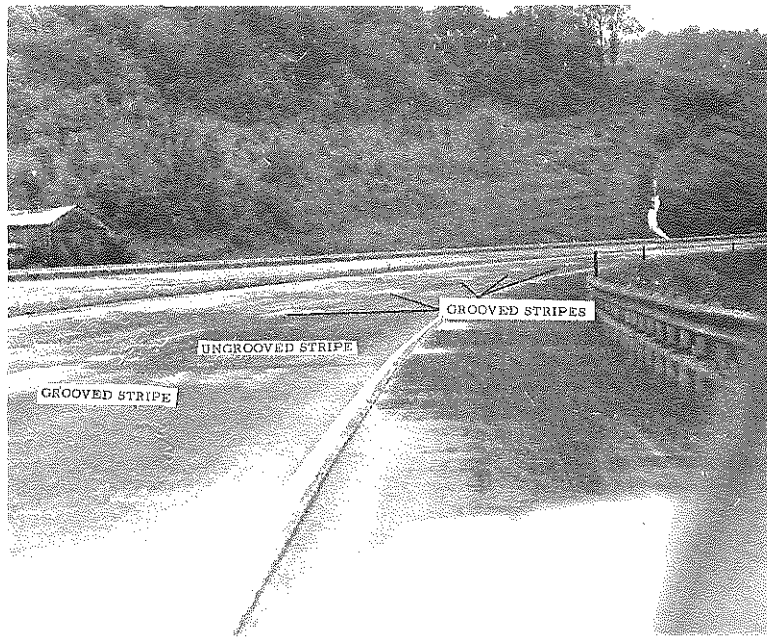


FIGURE 10 - Grooved Stripe Performance During Wet, Daytime Conditions



FIGURE 11 - Grooved Stripe Performance During Wet, Daytime Conditions

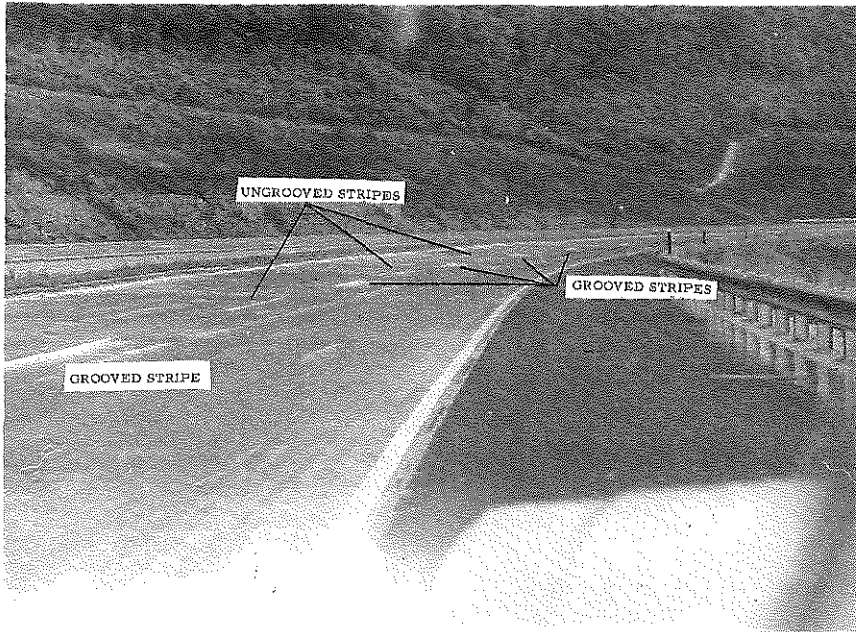


FIGURE 12 - Grooved Stripe Performance During Wet, Daytime Conditions